CLEAN VERSION OF AMENDED SPECIFICATION PARAGRAPHS

IMPROVED BOLOMETER OPERATION USING FAST SCANNING
Applicant: Roland A. Wood
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Amended paragraph beginning on page 2, line 26:

In the prior art, one single bias pulse is applied to each microbolometer in the array in each frame time. Application of a single bias pulse in each frame time can result in a temperature increase in the microbolometer over and above the heating effect of the incident radiation. Since, by necessity, such bias pulses have to be much shorter in time than the frame time, the heating effect is very rapid. Thus, when one bias pulse is applied to each microbolometer in the array in each frame time, the temperature of the microbolometer can initially rise rapidly for a short time equal to the bias pulse duration, and then fall for the reminder of the frame time. The variation in the signal level during each bias pulse due to the temperature rise and fall can typically be many times greater than the signals caused by the incident radiation. The electronic circuits receiving the signals must be designed to possess a much larger dynamic range than would be required for the radiation signal alone. This adds to the difficulty in designing and operating such circuits.

Amended paragraph beginning on page 3, line 7:

The minimum infrared signal that can be detected by a microbolometer is determined by the electrical noise present in the resulting current signal. The "noise equivalent power" (NEP) of a microbolometer may be defined as the infrared radiation power change incident on a microbolometer that induces a signal current change equal to the "root mean square" (rms) current noise. Also, the "noise equivalent temperature difference" (NETD) is another term that is generally used in describing the performance of a microbolometer array. The NETD is defined as the temperature change at a target that produces a signal current change in the microbolometer equal to the rms current noise. In summary, the performance of the microbolometer array is generally measured in terms of the magnitudes of the NEP or NETD of

the microbolometers used in the array. Generally, lower values of NEP and NETD correspond to a higher sensitivity and improved performance of the microbolometer array.

Amended paragraph beginning on page 3, line 18:

The existing method for obtaining higher sensitivity and improved performance in a microbolometer is to increase the magnitude of the bias pulse. However, higher bias pulse magnitudes produce correspondingly higher heating pulses and temperature variations in the microbolometer. This increase in heating pulse and temperature variation increases the dynamic range requirement of the circuits receiving the microbolometer signals.

Therefore, there is a need in the art to design and operate ROICs such that they operate at a significantly lower NEP and NETD values from a microbolometer array, to improve the sensitivity and performance of the microbolometer arrays. Also, there is a need in the art to reduce the microbolometer temperature variations within the frame time caused by the application of bias pulse heating effect.

Amended paragraph beginning on page 3, line 27:

The present invention provides a method and apparatus to apply two or more bias pulses substantially sequentially to each of the one or more microbolometers in an array, such that the resulting temperature in each of the microbolometers is substantially uniform during a frame time, and measure two or more resulting signals associated with each of the applied two or more bias pulses during the frame time. Further, computing an average signal value from the measured two or more resulting signals for each of the microbolometers in the array during the frame time. Thereafter, producing an output signal based on the computed average signal value to improve performance, sensitivity, and facility of operation of the array.

Amended paragraph beginning on page 5, line 24:

Figure 2 illustrates one embodiment of a ROIC 115 used in forming the microbolometer array 110. Each microbolometer in the array 110 is represented as an electrical resistor 220. Associated with each microbolometer 220 in the array 110 is a field-effect transistor (FET) 230. The microbolometers 220 and the FETs 230 are interconnected by thin-film metallic conductors 240. The ROIC 115 further includes column and row shift registers 250 and 260. The column shift register 250 applies control voltages to columns of the array 110, and the shift register 260 applies control voltages to a row multiplexer 270. A global bias voltage is applied to all the microbolometers in the array 110. The output signal line 280 of the array 110 is held at zero volts by an external connection. In operation, the ROIC 115 applies control voltages so that only one microbolometer has an applied bias voltage (VDDR) across it, and a signal current flows along the corresponding thin-film metallic conductor 240, through the multiplexer 270, and out to the output signal line 280. Additional current is supplied from a voltage source 290 via a resistor 292 to substantially bring the net output current 294 close to zero. The voltage source 290 can apply different bias voltages (as noted in U.S. Patent No. 4,752,694) to different microbolometers 220 in the array 110 during each time interval the microbolometers 220 are being biased, so that the output current remains close to zero even if the resistance of different microbolometers have slightly different resistance values, due to small fabrication variations between different microbolometers 220 in the array 110. The signal zeroing process called the "coarse non-uniformity correction," together with other methods and apparatus to correct for coarse non-uniformity are taught in U.S. Patent No. 4,752,694.

Amended paragraph beginning on page 6, line 17:

Figure 3 illustrates a typical circuit 300 including integrator and an A/D converter connected to the output line 296 of ROIC 115 to convert the output current 294 to a digital signal value 370. The output current 294 from the output line 296 of the ROIC 115 is converted to a signal charge 310 and to a signal voltage 320. The signal voltage 320 goes through an analog-to-digital (A/D) converter 330.

Amended paragraph beginning on page 7, line 15:

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Graph 400 also illustrates temperature variation 440 of each microbolometer caused by the application of the bias pulse 430. It can be seen from the graph 400 that the temperature variation 440 of each microbolometer in the array 110 is quite significant in each frame time 410. This is because the heating effect of each bias pulse 430 itself causes the temperature to rise rapidly in each microbolometer as shown in the graph 400. This temperature rise is over and above the heating effect of the incident infrared radiation 130. Since by necessity, as described above, the time duration of each bias pulse 430 is significantly shorter than the frame time 410, the heating effect of each bias pulse 430 is very rapid. Thus, when one bias pulse 430 is applied to each microbolometer in each frame time 410 as shown in Figure 4, the temperature of each microbolometer in the array 110 initially rises rapidly 450, for a short time equal to the time duration 420 of the bias pulse 430. Then the temperature starts to fall 460 during the remainder of the frame time 410 as shown in Figure 4. The variation of signal level caused by this temperature variation 440 is significantly greater than the signals generated by the incident infrared radiation 130. Therefore, the ROIC 115 receiving such varying signals are designed to possess a much larger dynamic range than would be required for the signals generated by the incident infrared radiation 130 alone. The requirement of a large dynamic range by the ROIC 115 adds to the difficulty in designing and operating the ROICs.

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Amended paragraph beginning on page 8, line 1:

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Figure 5 is a graph 500 illustrating one embodiment of operating each of the microbolometers in the array according to the teachings of the present invention. Instead of a single bias pulse 430 applied in the prior art as shown in Figure 4, a series of two or more bias pulses 510 are applied substantially sequentially to each microbolometer in the array 110 within the frame time 410. The application of one or more bias pulses 510 to each of the microbolometers within the frame time 410 is referred to as "fast scanning."

[Amended paragraph beginning on page 8, line 8:]

Again, assuming an array size of 'R x C', and a frame time of 'T', each microbolometer in the array 110 could receive two or more bias pulses 510 having a time duration not exceeding (T/(N x R x C)) within the frame time 410. Alternatively, several microbolometers could be simultaneously provided with two or more bias pulses 510.

[Amended paragraph beginning on page 8, line 14:]

Graph 500 also illustrates temperature variation in each microbolometer caused by the application of two or more bias pulses 510. It can be seen that the temperature variation of each microbolometer in the array 110 in each frame time 410 is significantly reduced by the fast scanning technique of the present invention (by applying a series of two or more bias pulses within the frame time 410). This is because the heating effect of each bias pulse is reduced by the number of bias pulses applied within the frame time. If there are 'N' bias pulses applied within the frame time, the heating variation effect is reduced by a factor of N. Also, due to the application of a series of two or more bias pulses 510, the time duration 520 between each bias pulse 510 is shorter than the time duration 470 between bias pulses shown in Figure 4. This shorter time duration 520 between two or more bias pulses 510 allows less time for cooling to occur, thereby keeping the temperature variation to a minimum 530 as shown in Figure 5.

[Amended paragraph beginning on page 8, line 21:]

The reduced temperature variation allows the use of electronic circuits with higher performance. Another reason for the performance improvement provided by the fast scanning method 500 shown in Figure 5 relative to the prior art method of applying one bias pulse 430 to each microbolometer in the array in each frame time 410 shown in Figure 4, as can be

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understood as follows: If the number of bias pulses N applied in each frame time to each microbolometer in the array 110, is greater than 1, and each is N times shorter in duration than the single bias pulse 430 that could be applied, then the noise bandwidth of the signals is increased to a higher frequency limit by a factor of N. Each signal therefore has $N^{1/2}$ greater white noise, but there is no increase in the 1/f noise, since such low frequency noise is assumed to lie substantially within the noise bandwidth for all values of N. If the N signal values from each microbolometer in each frame time are used to form an average signal value, the rms white noise is reduced to the N=1 value, and the low frequency noise rms value for noise frequencies approximately between the frame repetition rate frequency and the bias pulse repetition frequency is approximately reduced by the factor of $N^{1/2}$ below the N=l value. Thus, the final signal value that is obtained in each frame time has a reduced amount of noise if N>1. The reduced noise produces corresponding improvement factors in the array performance (reduced values of NEP and NETD).

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[Amended paragraph beginning on page 9, line 9:]

Figure 6 shows a graph of calculated NEP versus level of applied input bias current pulses when scanning the array 110 shown in Figure 1 using the prior art technique. Figure 7 shows a graph of calculated NEP versus level of applied input bias current pulses when scanning the array 100 shown in Figure 1 according to the present invention. All the parameters used in computing the NEP for the graphs shown in Figures 6 and 7 are kept constant during the scanning of the array 110 except for the application of bias current pulses. It can be seen from the two graphs in Figures 6 and 7, that the calculated NEP in Figure 7 is very much lower (with increasing input bias current) when compared with the calculated NEP in Figure 6. This is due to the application of one or more bias current pulses according to the present invention, which results in a reduction in noise in the ROIC. As described earlier, the reduced noise results in improved array performance.

Amended paragraph beginning on page 10, line 22:

Figure 9 illustrates major portions of an infrared radiation detector apparatus 900 and their interconnections according to the present invention. The infrared radiation detector apparatus 900 includes the microbolometer array 110, ROIC 115, and an output circuit 950. The ROIC 115 includes a timing circuit 920, a measuring circuit 930, and a computing circuit 940.

Amended paragraph beginning on page 10, line 26:

The timing circuit 920 is coupled to the microbolometer array 110 such that the timing circuit 920 can apply two or more bias pulses substantially sequentially to each of the microbolometers in the array 110 such that the resulting temperature in each of the microbolometers in the array 110 due to the application of the two or more bias pulses 510 is substantially uniform during a frame time 410. The frame time 410 is the time it takes for the microbolometer array 110 to produce a complete image of an object being viewed by the microbolometer array 110. The operation of the microbolometer array 110 has been described in detail with reference to Figures 1 and 2.

Amended paragraph beginning on page 11, line 6:

In some embodiments, the two or more bias pulses 510 are substantially equal in magnitude. The two or more bias pulses 510 can be substantially equally spaced in time within the frame time 410. The two or more bias pulses 510 can be voltage bias pulses. The two or more bias pulses 510 can be current signals. The number of the two or more bias pulses 510 can be approximately in the range of about 2 to 100 bias pulses. The two or more bias pulses 510 have a time duration of approximately in the range of about 0.1 to 20 microseconds.

Amended paragraph beginning on page 11, line 13:

The measuring circuit 930 is coupled to the microbolometer array 110 such that the measuring circuit 930 can measure two or more resulting signals associated with each of the two or more bias pulses 510 applied during the frame time 410. The computing circuit 940 is coupled to the measuring circuit 930 so that the computing circuit 940 receives the two or more resulting signals from the measuring circuit 930 and computes an average signal value for each of the received two or more resulting signals from the measuring circuit 930. Then the output circuit 950 coupled to the computing circuit 940 produces an output signal based on the computed average signal value associated with each of the microbolometers in the array 110 such that the output signal improves performance, sensitivity, and facility of operation of the microbolometer.

Amended paragraph beginning on page 11, line 17:

In some embodiments, the output circuit 950 further includes an integrator and an A/D converter 300. The integrator and the A/D converter 300 receives the uniform output signal value associated with each microbolometer in the array 110 and converts the uniform output signal value to a digital signal value. The operation of the integrator and the A/D converter 300 has been discussed in detail with reference to Figure 3.

Amended paragraph beginning on page 11, line 22:

In some embodiments, the infrared radiation detector apparatus 900 further includes a digital image processor 340. The digital image processor 340 is coupled to the output circuit 950 to receive the digital signal value associated with each of the microbolometers in the array 110 and correct the received digital signal value for image defects such as fine offsets, gain non-uniformity, or dead pixels, and can further correct for any resistance non-uniformity in each microbolometer in the array (to obtain a uniform output signal value) using a correction circuit 360 to improve the image quality. The digital image processor 340 can further include digital

memories 350 to store the correction values associated with each of the microbolometers in the array 110.

Amended paragraph beginning on page 12, line 9:

The above-described method and apparatus provides, among other things, improved microbolometer array performance and sensitivity, as indicated, by lowering NEP and NETD. Also, the above method and apparatus produces a reduced microbolometer temperature variation in each of the microbolometers in the array.

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Amended paragraph beginning on page 17, line 6:

A method and apparatus to apply two or more bias pulses sequentially to each of the microbolometers in an array during a frame time such that the resulting temperature in each of the microbolometers of the array is substantially uniform during the frame time. Then measuring resulting current signals associated with each of the two or more bias pulses to produce an average signal value to improve sensitivity and performance of the array as measured by noise equivalent power and noise equivalent temperature difference.